

# California Air Resources Board

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## Engine Certification Workshop - Durability and Deterioration Factors

March 24, 2010

California Environmental Protection Agency



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# Applicable Categories

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- On-Road CA-Medium-Duty Engines (MDE)
- On-Road Heavy-Duty Otto-Cycle Engines (HDOE)
- On-Road Heavy-Duty Diesel Engines (HDDE)
- Off-Road Compression-Ignition Engines (OFCl--Tier 4i / Tier 4)
- Others (HD Hybrids & Special Cases)

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# Workshop Agenda

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- New Emissions Standards
- Use of New Emission Control Technologies
- Engine Durability Program / Generating New DFs
- Certification Issues



# New Emissions Standards

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# New Engine Emissions Standards

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- HDOE (CFR Part 86)
  - Otto FTP Transient
- HDDE (CFR Part 86 and Part 1065)
  - Diesel FTP Transient
  - SET (ramp-modal cycle: RMC)
- OFCI (CFR Part 89 and Part 1039)
  - Non-road Transient (NRTC)
  - Steady-State (C1 / D2 / etc.)

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# New Emission Control Technologies

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# New Emission Control Technologies

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- Exhaust Gas Recirculation (EGR)
- Diesel Particulate Filter (DPF)
- Selective Catalytic Reduction (SCR)



# EGR

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- Durability of EGR System
  - Valves
  - By-pass controls
  - Coolers
- Others
- Maintenance Intervals
- Deterioration Effects





# DPF

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- Infrequent Regeneration and Emissions Adjustment Factors (UAFs/DAFs)
- Ash Cleaning Event
- Operator Commanded Regeneration (OCR) for DPF is allowed under safe harbor provisions
  - See (CHC-2006-007-1)

# SCR

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- SCR system deterioration:
  - Linear vs. non-linear deterioration
  - Interaction w/ upstream and downstream ATD (OC, DPF, etc) and engine
  - Control sensors durability
- Toxics
  - Copper-based catalyst
  - Vanadium catalyst

# Applicable Regulations

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## On-Road CA-Medium-Duty Engines and Heavy-Duty Otto-Cycle Engines

- Exhaust and Evaporative Emissions Compliance CCR 1956.8
- 40 CFR Part 86 xxx-026
- Compliance to FUL
- Same as before



# Applicable Regulations

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## On-Road Heavy-Duty Diesel and Off-Road Compression-Ignition Engines

- Exhaust and Evaporative Emissions Compliance  
CCR 1956.8
- 40 CFR Part 86xxx-026 and Part 1039-240
- Compliance to FUL

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# Certification Requirements

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- Engine Durability to Defined Useful Life via service accumulation cycle + hours
- Emissions Compliance to Defined Useful Life via emissions deterioration factors for
  - Exhaust
  - Evaporative, as applicable

# Performance and Emissions Demonstration

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- Engine Durability Requirements
- Test Protocol and Test Procedures
- Durability Service Accumulation Cycle
- DF Calculations (~100% UL)
- Scheduled Maintenance and Emissions Testing

# Service Accumulation Duration

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- CA-MDE FUL = 120k miles
- On-Road HDOE FUL = 110k miles
- On-Road HDDE LH/MH/HH 50% FUL
- OFCI 50% of FUL
- Optional DF for HHDDE/OFCI: 35% FUL +

## 2 DFs to be Generated

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One service accumulation cycle producing 2DFs:

- HDDE Category (2007+)
  1. DF1 = FTP Transient Cycle
  2. DF2 = ramp-modal cycle (RMC)
- OFCI Category (Tier4i / Tier4)
  1. DF1 = Non-Road Transient Cycle (NRTC)
  2. DF2 = Steady State



# Emissions Test Points / Intervals

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- Minimum of three, equally spaced test points, throughout service accumulation period (recommend every 250 hours)
- FTP / NRTC: test sample point = 1 cold start + 3 hot starts
- RMC / C1 / D2: test sample point = 3 hot starts
- Equal sampling at each test sample point

# Service Accumulation Cycle

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- Service accumulation hours
- Transient segments required
- Real-life or in-use engine cycle
- Emissions testing hours excluded from total cycle
- Recommend agency pre-approval

# Deterioration Factors

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- Separate Factors for Each Pollutant
- Useful Life Projected Values
- Applied to EDE to Show FUL Compliance

# DF Calculation

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- Must include all data collected
- Engines with after-treatment: Multiplicative
  - xxHC, NO<sub>x</sub>, CO, HCHO
  - PM additive
- Engines with no after-treatment: Additive
- Will consider alternatives

# DF Calculation (continued)

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- Individual pollutant with separate DF
- DF for composite xxHC+NOx standard
- May use least-square linear regression method
- May propose other calculation methodology

# Agency Pre-Approval for Special Cycles / Procedures

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- Special pre-conditioning procedures
- Special emission test procedures
- Any deviation from established protocols

# Durability Engine

## Allowable Maintenance

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- On-Road HDD, HDO, and MDE engines
- Applicability: 40CFR Part86xxx-025
- Highly recommend discussing maintenance schedule with agency
- May require before and after emissions tests

# Durability Engine

## Allowable Maintenance

(continued)

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- OFCI for all Tier 4i and Tier 4 engines
- Applicability: 40CFR Part 1039.125
- Highly recommend discussing maintenance schedule with agency
- May require before and after emissions tests



# Certification Issues

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# Certification Issues / Items

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- Unscheduled maintenance
- DF engine “failures”
- DPF ash-cleaning event
- DF carryover / carry-across
- Future DF protocol

# Durability Engine

## Unscheduled Maintenance

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Recommend seeking Agency pre-approval,  
Example:

- Cleaning, replace, or repair of :
  - EGR (system), injectors, turbocharger, after-coolers, and by-pass controls
- After-treatment device replacement
- Calibration changes

# What to do with DF Engine/Part Failure

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1. Do NOT replace, repair, clean, or modify the DF engine or engine part(s)
2. Identify and diagnose failure and impact of failed part(s)
3. Contact agency for guidance

# What to do with DF Engine/Part Failure (continued)

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4. Seek approval from agency for any maintenance of the DF engine
5. Agency will consider appropriate action for the DF engine
6. Must provide engineering report of failure in application

# Collection of DPF Ash Cleaning and Resultant Emission Data

- If an ash cleaning is required within the FUL, this event must be demonstrated
- Emissions testing before and after the ash cleaning event
- Emission data will be used to validate the cleaning procedure
- Collected data may be part of the DFs

# DFs: Carry-Over & Carry-Across

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- Allowed for comparable engines
- Carry-over to a different model year  
(minor changes w/o emissions impact)
- Carry-across between engine families
  - Worksheet to be completed
  - Worksheet available on ARB website

# Sample C/O and C/A Worksheet

DF Carry-across comparison parameters						
1	Engine Family	Tested Family				
2	Engine Type					
3	Number of Cylinders					
4	Cylinder Head Configuration					
5	Displacement					
33	Reducing agent/fuel consumption ratio (Volumetric) per 1000 Hours of Operation					
34	Catalyst surface area/Max. Power					
35	Type of Oxygen Sensor					
36	Maximum Exposure Temperature on Oxygen Sensor					
37	Type of NOx Sensor					

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# DFs: Carry-Over & Carry-Across (on-road to off-road)

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Comparing these follow items:

- Engine hardware/software
- In-use characteristics
- Durability cycle
- Emissions test cycles
- Engine duty-cycle, engine-load and performance, and control calibrations

# ARB May Consider Accepting Alternative DF Protocol

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- Case by case approval
- Rapid Alternative Durability Process (RADP)
- Real-world, In-use validations
- Engine-out vs. tailpipe-out
- Rapid aging (bench aging protocol)

# Other Items of Interest

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- AECD sensors table (available on ARB website)
- Engine emissions label durability and alternative protocol to demonstrate label durableness
- Provide physical labels for testing

# Sample Sensors Table

Line Number	Sensor or Actuator Name / Abbreviation	Sensed Parameter Range : High / Low (Units)	Sensor - Actuator Value : High (unit)	Sensor / Actuator Value : Low (unit)	sensor still working? (yes / no)	Failure Detection	Failure Indication	Default Mode / threshold value	Failure Consequence	Impacts on Emissions	AECD Type	AECD Justification	ARB staff comment
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# Other Items of Interest (continued)

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- California Warranty
- HD-ZEV and HD-Hybrid rulemaking process
- HD Hybrid DF protocol
- OBD aged-part considerations

# Compression-Ignition and Heavy-Duty Certification

**Manager: Kim Pryor**

(626) 575-6640 [kpryor@arb.ca.gov](mailto:kpryor@arb.ca.gov)

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Paul Adnani

Zachary Evans

James Pang

Michael Pham

Tom Chang

Tsatsu Nukunya

Babak Pazokifard

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# Questions and Answers

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Q ??? / A !!!

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